



## **MINBAR: A comprehensive study of 6000+ thermonuclear shell flashes from neutron stars**

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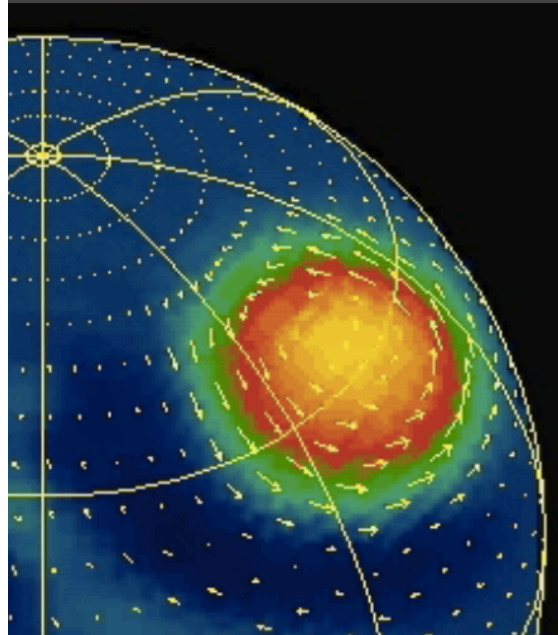


Science

# MINBAR: A comprehensive study of 6000+ thermonuclear shell flashes from neutron stars

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X-ray Universe, Dublin, Ireland  
19<sup>th</sup> June 2014



## Multi-INstrument Burst ARchive

This page provides a web-based search and display interface to the Multi-INstrument Burst ARchive of thermonuclear (type-I) X-ray bursts observed by the [Rossi X-ray Timing Explorer](#).

The data provided here is **PRELIMINARY** and **NOT SUITABLE FOR PUBLICATION**.

For more information, see the [project home page](#), the [project wiki](#) or contact the PI.

For more information on the data fields, click [bursts](#), [observations](#), [sources](#)

Data Source :

☒ Bursts ☐ Observations ☐ Sources

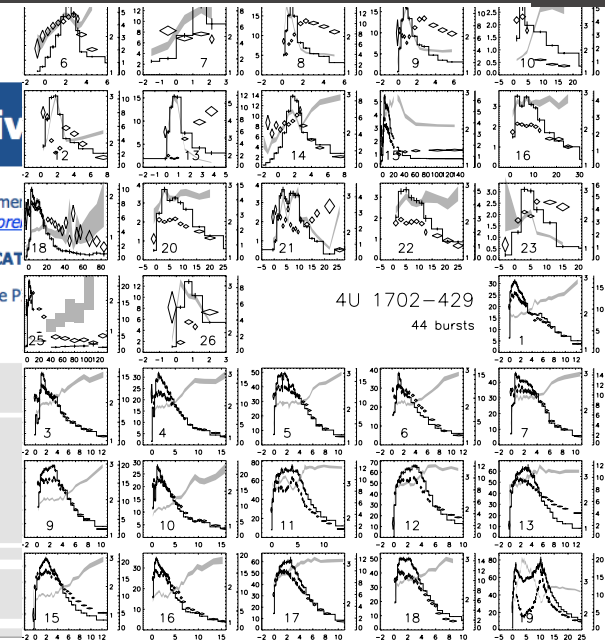
Display :

name,time,instr

Add a field

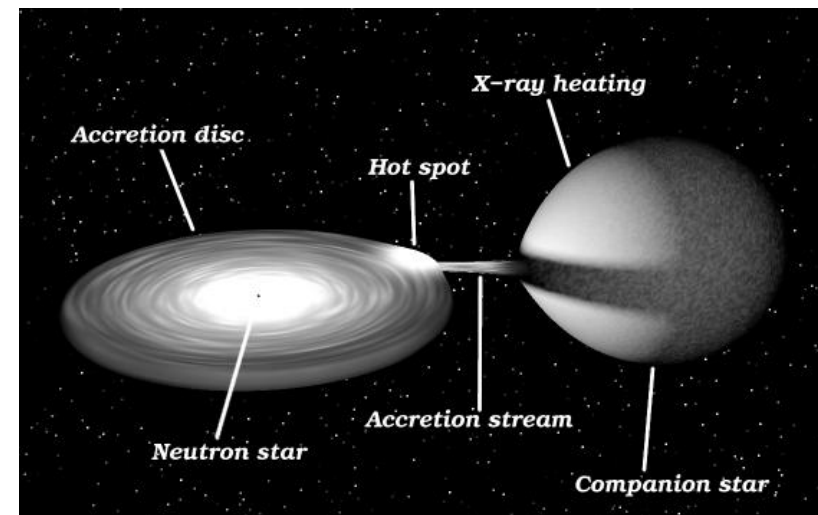
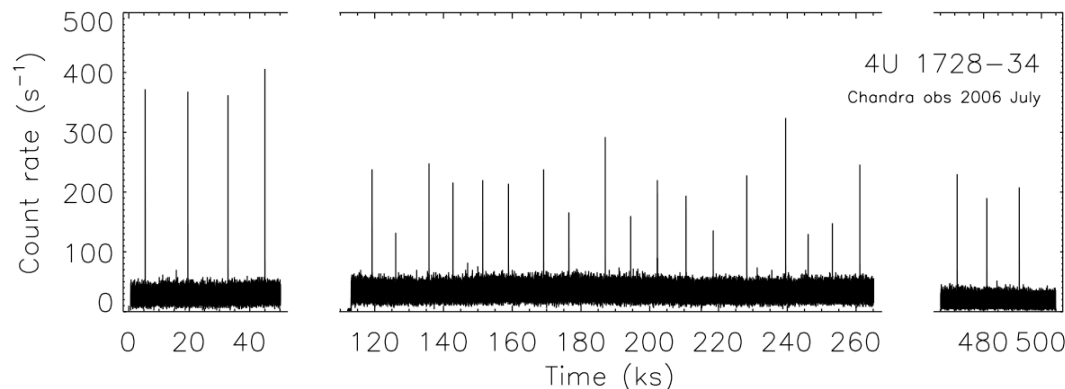
Filter :

Select a query field to filter



# Thermonuclear X-ray bursts

- Caused by unstable ignition of accreted fuel (H+He or ~pure He) on the surface of neutron stars accreting from low-mass binary companions; ~100 bursters known



- Typical recurrence time (at accretion rates of 10% Eddington) is a few hours; peak fluxes of  $10^{38}$  erg/s; fluences of  $10^{39}$ – $10^{40}$  erg
- Burst properties vary dramatically with accretion rate, and even source (persistent) spectral state see *poster B6 (Jari Kajava)*

# Thermonuclear burst observations

- Thermonuclear burst research has benefited over the last 20 years from two long-duration missions – *BeppoSAX* and *RXTE* – with broad science goals leading to extensive observations of many burst sources
- ESA mission *INTEGRAL* provides ongoing wide-field coverage of burst sources with JEM-X and ISGRI
- There are also smaller datasets accumulated from observations by *XMM-Newton*, *Chandra*, *Swift* etc.
- The result is an extensive (and still growing) archive of tens of thousands of observations of burst sources, containing more than 6000 individual events
- Much phenomenology is understood, but there are several open science questions that remain unanswered



# Open questions

- What conditions give rise to *short recurrence time bursts*? e.g. Boirin et al. 2007, A&A 465, 559
- Why does the burst rate *decrease* for most sources as the accretion rate increases? e.g. Cornelisse et al. 2003, A&A 405, 1033
- Why do bursts appear to cease for most sources *well below* the Eddington accretion rate, where theoretical models predict they should? e.g. Fujimoto et al. 1981, ApJ 247, 267

Short campaigns on individual sources typically span a limited range of accretion rates, so it is difficult to address these questions observationally. Furthermore, the diversity of burst sources make it risky to generalise e.g. van Paradijs et al. 1988, MNRAS 233, 437

These issues motivate large *population* studies of bursts drawing from all the available public data

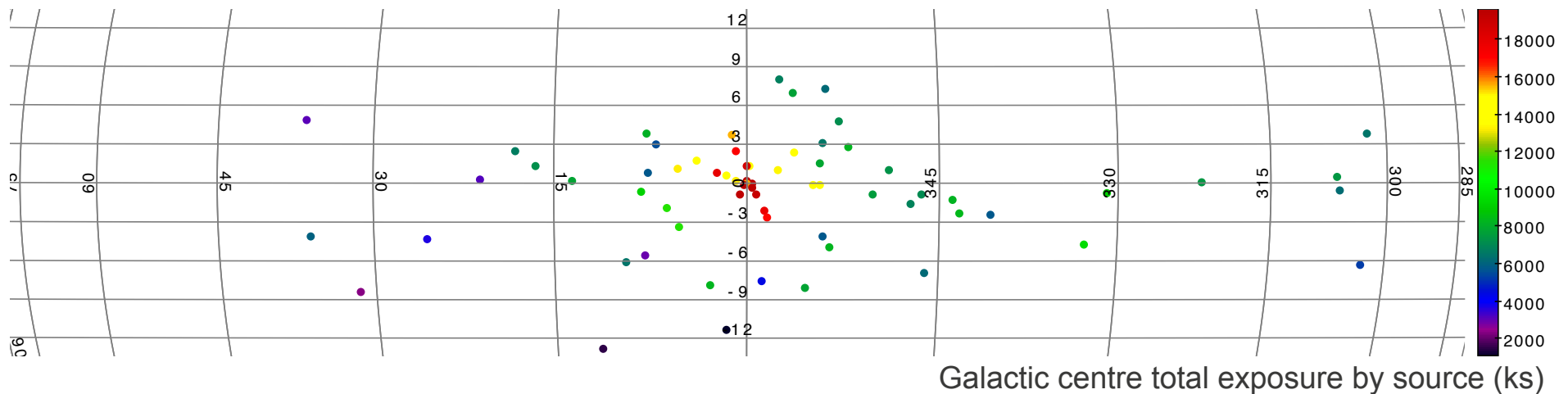
# The Multi-INstrument Burst ARchive



- Extension of the sample of 1187 bursts observed by the *Rossi X-ray Timing Explorer (RXTE)* from 48 sources Galloway et al. 2008, ApJS 179, 360
  - Incorporated additional ~1000 bursts observed by *RXTE* through to the end of mission (2012 Jan);
  - ~2200 bursts observed with the *BeppoSAX* Wide-Field Camera (WFC)
  - ~2500 bursts detected by the JEM-X cameras onboard *INTEGRAL*; further observations ongoing
- Currently 6909 thermonuclear bursts from 84 burst sources (v0.7); companion observation table includes 233792 observations from 99 sources
- Data analysis underway; goal is to provide uniform analysis of individual bursts, including peak flux, fluence, lightcurve parameters, and time-resolved spectroscopy (where signal permits)

## Science exploitation of the catalog

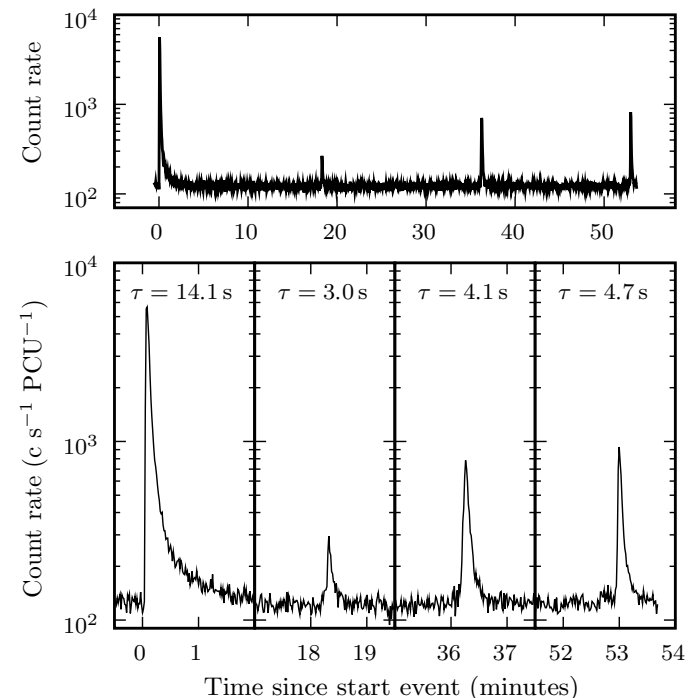
- Has been limited so far in the assembly phase; papers benefiting from this work listed at <http://goo.gl/TQRxpr> (8 papers, 58 citations)
- More details, including summaries of burst totals per source and source list, at the project Wiki: <http://burst.sci.monash.edu/minbar/wiki>
- Median exposure is 8 Ms; got over 1000 bursts from 4U 1728–34, 644 from 4U 1636–536





# Short recurrence time bursts

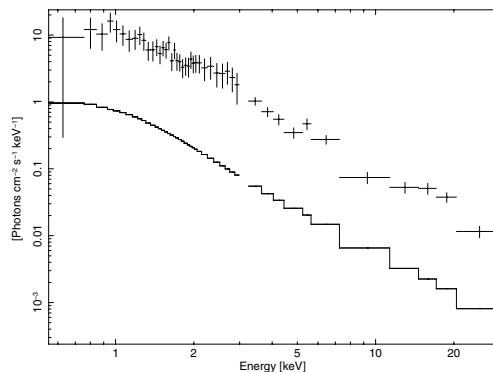
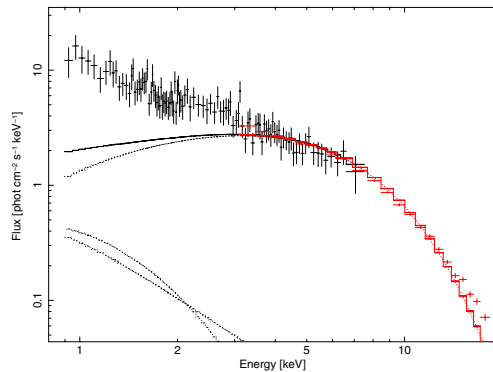
- These events recur after intervals as short as 3.8 min – undoubtedly thermonuclear, but this is too brief to reach the critical pressure and temperature to achieve ignition
- Keek et al (2010, ApJ 718, 292) analysed 136 bursts from MINBAR with recurrence times shorter than 1 hr
- Such bursts occur in groups of up to 4; are seen from 15 sources; and never from ultracompact sources or those thought to accrete pure He
- Spin periods, where known, are all *fast* (~500 Hz) suggesting a role for rotationally-induced mixing
- Modeling efforts are ongoing





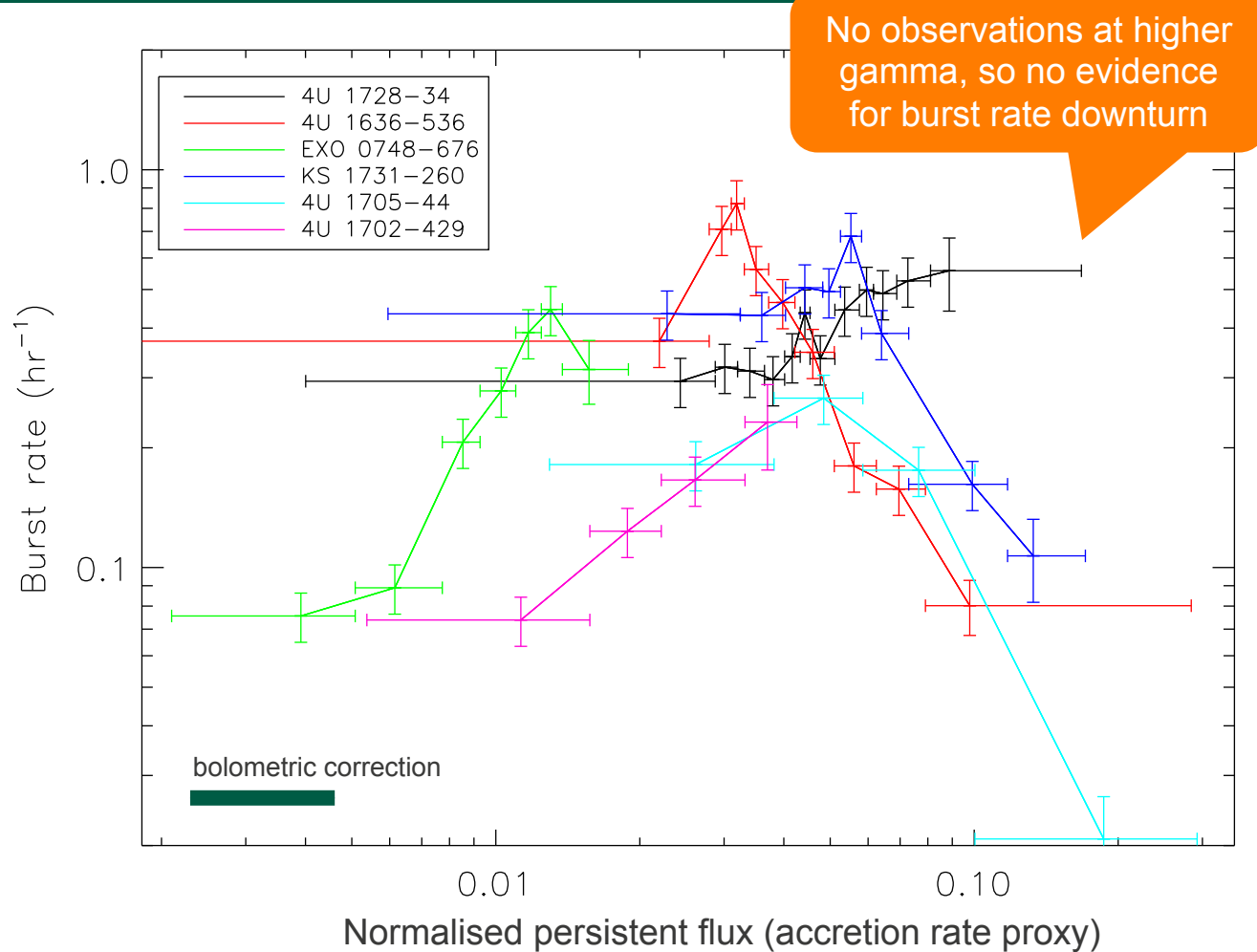
# Variable persistent flux

- Efforts to better test the standard blackbody net burst spectral fitting approach led to the finding that the fits are significantly improved if the pre-burst persistent spectral contribution is left free in the fits

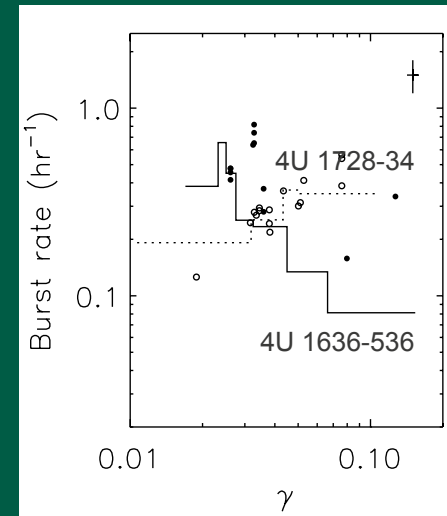


- Worpel et al. (2013, ApJ 772, #94) investigated first the photospheric radius-expansion (PRE) bursts, but subsequently this was also shown to be true in non-PRE bursts (**see poster J2**)
- This effect was also demonstrated in a remarkable *Chandra/RXTE* observation of a bright PRE burst from SAX J1808.4–3658 in 2011
- in ‘t Zand et al. (2013, A&A 553, 83) found increases in the persistent flux contribution of up to a factor of 20

# Burst rate for six sources



*RXTE* burst catalog  
(Galloway et al. 2008)

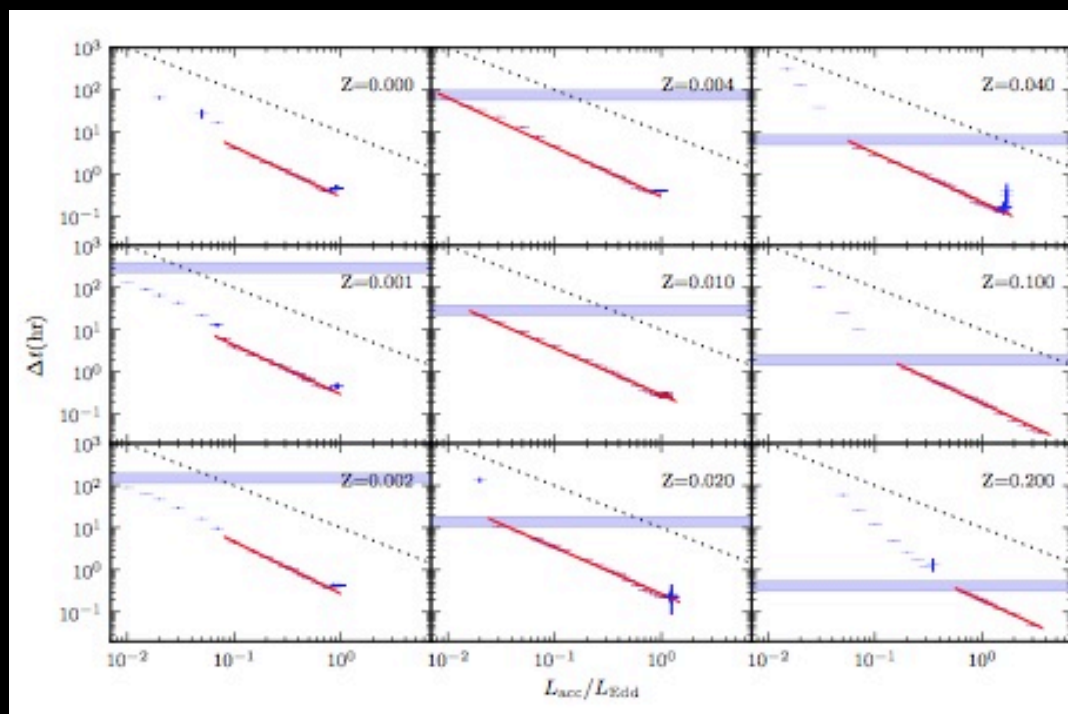


## KEPLER models

Monash student Nathanael Lampe has analysed a large sample of KEPLER (Woosley et al. 2004 ApJS 151, 75) burst model results

In a companion effort to MINBAR we have measured burst recurrence time and burst properties for a wide range of input conditions; ultimate goal is using this sample to make detailed comparisons with observations

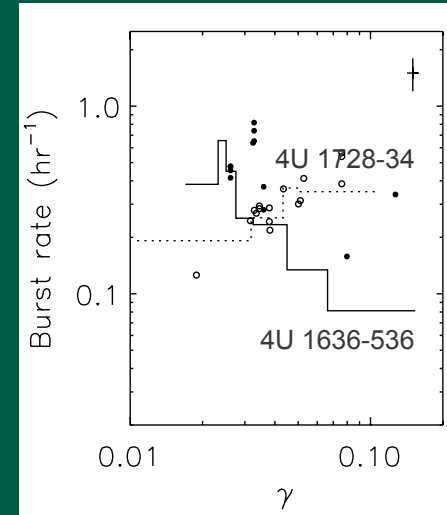
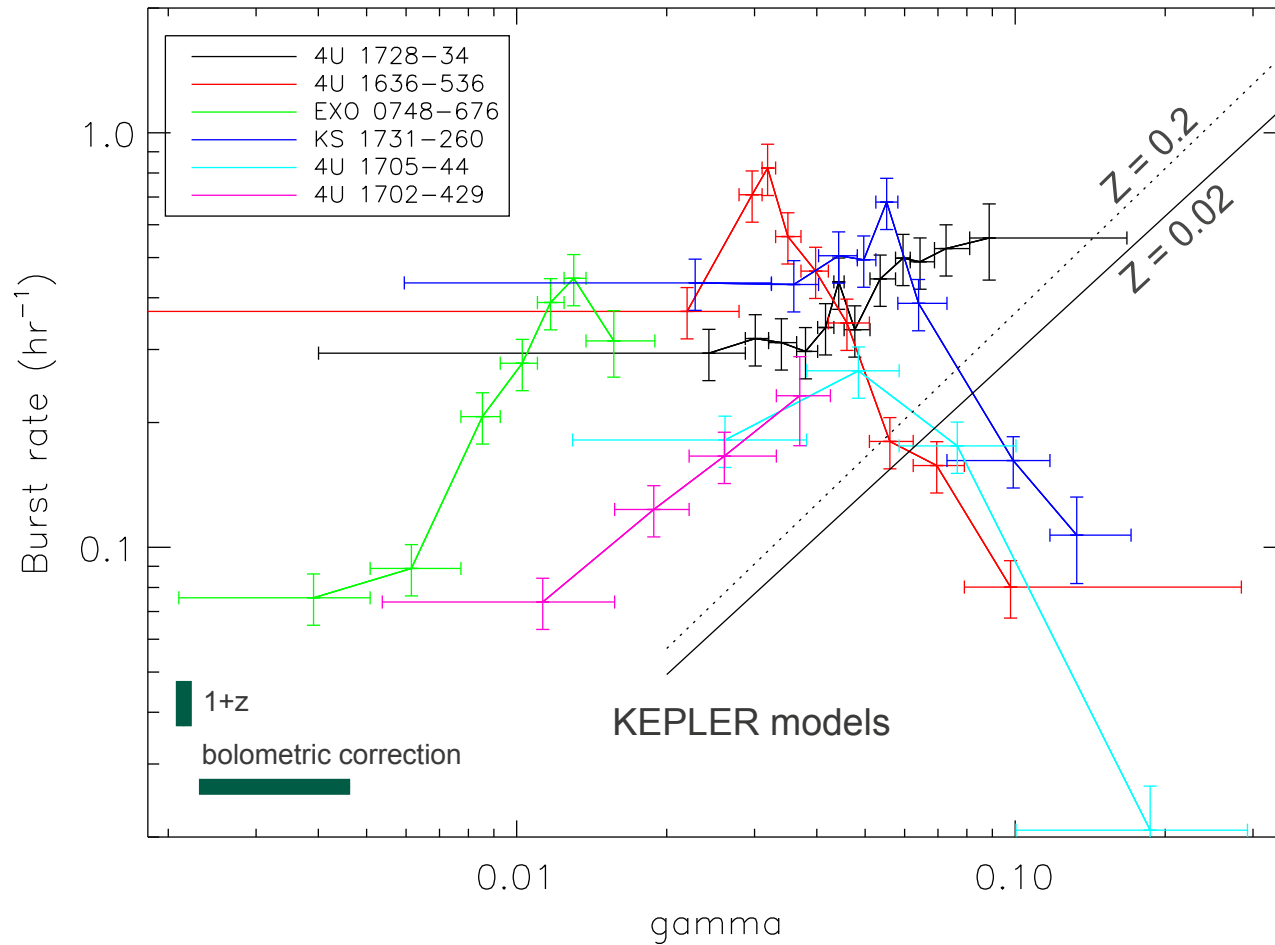
These analyses results will be released shortly as a paper and data tables



Burst recurrence time as a function of accretion rate, for different metallicities. **Red lines** are power-law fits in the region of “Case 3” (mixed H/He burning). **Blue bands** are the expected recurrence time at which the transition to “Case 2” (pure He) bursts occurs

# Burst rate for six sources

*RXTE* burst catalog  
(Galloway et al. 2008)



# Summary and future work



## Multi-INstrument Burst ARchive

This page provides a web-based search and display interface to the Multi-INstrument Burst Archive (MINBAR) version 0.51, comprising analyses of thermonuclear (type-I) X-ray bursts observed by the [Rossi X-ray Timing Explorer \(RXTE\)](#), [BeppoSAX](#) and [INTEGRAL](#).

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<b>Data Source :</b>	<input checked="" type="radio"/> Bursts <input type="radio"/> Observations <input type="radio"/> Sources			?
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<b>Filter :</b>	<input type="text" value="Select a query field to filter"/>			<input type="button" value="+"/> ?

web interface at <http://burst.sci.monash.edu>



- Continued integration work on data in-hand; propagate through to web interface
- Spectral fits of JEM-X data
- Inclusion of *XMM-Newton* and *Chandra* data?
- Instrumental cross-calibration
- Publication & data release